Biological rhythms
Biological rhythms

If luteinizing hormone in hamsters is measured...

...hourly

...daily

...annually
Rhythms and clocks

Rhythm: biological event that repeats

Clock: mechanism for tracking rhythm
Early evidence

Extra-ocular perception

Temperature compensation
Rhythms and clocks

“zeitgebers”

Clock-setting pathway: Sunlight or other environmental cues → Sensory receptors → Pacemaker

Clock mechanism: Pacemaker → Observed rhythms
  - Locomotory patterns
  - Feeding behaviors
  - Hormone release patterns
  - Other rhythms
Endogenous rhythms

free-running rhythm or cycle (endogenous)

24 hr light

12 hr light:
12 hr dark

Teleogryllus commodus

entainment
Aschoff’s rule

- Direction of drift depends on normal circadian rhythm
- Total darkness:
  - < 24 hr if nocturnal
  - > 24 hour if diurnal
- Total light:
  - < 24 hr if diurnal
  - > 24 hour if nocturnal
Aschoff’s rule

12:12 light:dark

24 dark

activity
Aschoff’s rule

Teleogryllus commodus
Types of rhythms

1. Ultradian
2. Circatidal
3. Circadian
4. Infradian
5. Circalunar
6. Circannual

Ultradian = periodicity < 24 hours
Circatidal rhythms
Infradian rhythms

Periodicity > 24 hours

Periodical cicada

I, II, III, IV, V, VI, VII, VIII, IX, X, XIII and XIV – 17 year cicadas
XIX, XXII and XXIII – 13 year cicadas

Significance of prime number?

Brood XIV in ‘08

cicada killer
Circalunar rhythms

Volume of antlion pits
Circannual rhythms

stonechat

Testicular width (mm)

1982
1983
1984
1985
1986
1987
1988
1989

Month

Vernal equinox
Summer solstice
Autumnal equinox

“Spontaneous” testicular regeneration
Pineal-induced testicular degeneration
Importance of circannual rhythms for tropical migrants
## Free-running rhythms

<table>
<thead>
<tr>
<th>Rhythm type</th>
<th>Entrained</th>
<th>Free-running</th>
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</thead>
<tbody>
<tr>
<td>Circadian</td>
<td>24 hours</td>
<td>22-26 hours</td>
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<tr>
<td>Circatidal</td>
<td>12.4 hours</td>
<td>11-14 hours</td>
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<tr>
<td>Circalunar</td>
<td>29.5 days</td>
<td>26-32 days</td>
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<tr>
<td>Circannual</td>
<td>365.25 days</td>
<td>330-400 days</td>
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</tbody>
</table>
Non-photic zeitgeber

Temperature

Water
Importance of social cues

Round-the-clock care by nurse bees

Circadian rhythm when bee removed from colony

Actogram of forager
Importance of social cues
When zeitgebers are absent

But wait!

naked mole rat

<table>
<thead>
<tr>
<th>Individuals</th>
<th>Time</th>
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<tr>
<td></td>
<td>12:30</td>
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<td></td>
<td>00:30</td>
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<tr>
<td></td>
<td>12:30</td>
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<tr>
<td>K-3 (Queen)</td>
<td></td>
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<tr>
<td>Day 1</td>
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<tr>
<td>Day 2</td>
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<td>Day 3</td>
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<td>K-17</td>
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<td>Day 1</td>
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<td>Day 2</td>
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<td>Day 3</td>
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<td>K-F</td>
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<tr>
<td>Day 1</td>
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<td>Day 2</td>
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<td>Day 3</td>
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<tr>
<td>TT-- (Queen)</td>
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<tr>
<td>Day 1</td>
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<td>TT-Z</td>
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<td>Day 2</td>
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<tr>
<td>Day 3</td>
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</tr>
</tbody>
</table>

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When zeitgebers are absent

Arrhythmia in blind cavefish

No cycle in clock-regulated (top) or light-regulated (bottom) genes

opsin genes mutated!
Light is not the only zeitgeber

Cyclicity of zebrafish and cavefish *Per* and *Clk* expression
Location of biological clock

Monarch butterflies have two, one controls circadian rhythm *per* activity and adult emergence disrupted in constant light environment.

More on insect clocks on Friday.
Location of biological clock

...other controls time-compensated compass
Humoral signals

Night vs. dawn eclosion of two moth species
Location of biological clock

Birds and reptiles: pineal stimulated directly
Tuatara (*Sphenodon punctatus*) has well-developed parietal eye.
Mammals: suprachiasmatic nucleus (SCN) in hypothalamus